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DESIGN OF DUAL BAND 1X2 MICROSTRIP PATCH ANTENNA ARRAY FOR GPS RECEIVERS

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ABSTRACT

An 'H' shaped dual band micro-strip patch antenna array is designed, simulated and fabricated for Global Positioning system (GPS) receivers covering L1 and L5 frequencies of 1.575 GHz and 1.176 GHz respectively. Antenna parameters like return loss, VSWR, impedance matching, radiation pattern and directivity are analyzed. The designed antenna has a bandwidth of 1.3% and 2.2% for GPS L1 and L5 receivers respectively. In addition to it, the micro-strip patch antenna array is fabricated using co-axial feed mechanism and tested. The antenna had a return loss of -27 dB and -18 dB for GPS L1 and L5 band respectively.

Keywords: array antenna, micro-strip patch antenna, GPS receivers.

1. INTRODUCTION

In the last decades, there has been a rapid growth in the antenna design of integrating GPS into terrestrial wireless communication system. Global Navigation Satellite System (GNSS) is the standard universal term for radio navigation satellite systems that provide autonomous geo-spatial positioning with global coverage. The GNSS permits receivers to determine their location using signals transmitted from satellites. Aviation receivers utilizes GPS L1 and L5 radio navigation [1].

Micro-strip patch antenna has been wide employed in several applications due to low cost, low profile and easy fabrication [2]. The antenna is designed for a GPS satellite system navigating receiver, operating at 1.575 GHz and 1.176 GHz frequency bands. In the literature, a number of studies on a dual band operation covering GPS L1 and L2 frequencies [3]-[4] have been reported along with mobile applications [5]-[7].

This paper proposes a co-axial feed array antenna for GPS operation in L1 and L5 band. This paper is organized as follows: Section II describes the structure and design of the single patch and array antenna, Section III shows the results and discussion, while the paper is concluded in Section IV.

2. ANTENNA DESIGN

The geometry of the designed array antenna is shown in the Figure-1. It is composed of two identical patches, two co-axial feed and a ground plane. The patch antenna is employed with two vertical slots that are responsible for GPS L1 band frequency resonance and one horizontal slot that is responsible for GPS L5 band frequency resonance. The electrical length is altered by cutting slot such that the current doesn't flow in the opposite direction [8]-[9].

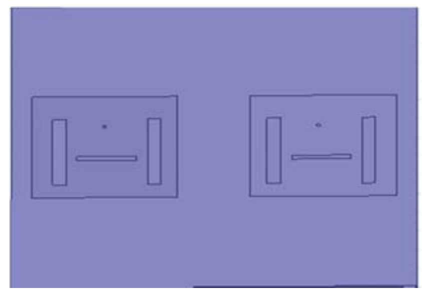

Figure-1. Geometry of the array antenna.

The dimension of the single patch antenna is shown in the Figure-2 and can be calculated with the following equations [10]-[13].

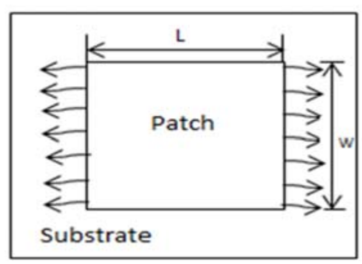

Figure-2. Patch antenna dimension.

Width

The width (W) of the patch antenna controls the input impedance and radiation pattern and is given as

$$W = \frac{c}{2f\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \quad (1)$$

Where,
c = Velocity of light = $3\text{x}10^8$ m/s
f = Resonance frequency = $1.37\text{x}10^9$ Hz
ε_r = Dielectric constant = 4.4 (FR4 substrate)

Effective dielectric constant

Most of the electric field lines reside within the substrate and a few in the air as shown in Figure-2. Hence effective dielectric constant, ε_{reff} must be determined in order to take in account of the fringing field and wave propagation in the line. The effective dielectric constant (ε_{reff}) can be given as

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{\left(1 + 12\frac{h}{w}\right)}}\right] \quad (2)$$

Where,
h = height of the substrate = 1.6 mm

Length

The fringing fields along the width of the structure as shown in the Figure-2 are taken as radiating slots. Due to this, the dimension of the patch antenna will be seen electrically bit larger than the initial dimension. This variation in dimension is named as extended length (ΔL) that is given by

$$\Delta L = 0.412\, h \frac{(\varepsilon_{reff} + 0.3)}{(\varepsilon_{reff} - 0.258)} \frac{\left(\frac{w}{h} + 0.264\right)}{\left(\frac{w}{h} + 0.8\right)} \quad (3)$$

The actual length of the patch antenna will be calculated from the subsequent equation

$$L = L_{eff} - 2\Delta L \quad (4)$$

Where,
L_{eff} = Effective length of the patch

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}} \quad (5)$$

Feed position

The feed coordinates are calculated using the following equations

$$X_f = X_o - \Delta L \quad (6)$$

$$Y_f = \frac{W}{2} \quad (7)$$

Where,

$$X_o = \frac{L}{\pi}\cos^{-1}\sqrt{\frac{50}{Z_o}} \quad (8)$$

$$Z_o = \sqrt{50 * Z_{in}} \quad (9)$$

The position of the feeding probe is optimized by heuristic approach so as to achieve a better impedance matching. The detail dimension of a single radiating patch is given in the Figure-3. The patch surface is 53.76 x 53.76 mm^2, while the horizontal and the vertical slot dimension is 2 x 22 mm^2 and 35 x 5 mm^2, respectively.

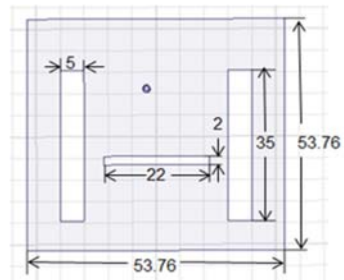

Figure-3. Geometry of single patch antenna.

Summary of the design

Table-1. Dimension of the designed antenna.

Parameter	Dimension
Center frequency	1.37 GHz
Length of the patch (L)	53.76 mm
Width of the patch (W)	53.76 mm
Height of the substrate (h)	1.6 mm
Dielectric constant (ε_r)	4.4

3. RESULTS ANS DISCUSSIONS

The simulation is carried out using the commercially available electromagnetic simulation software HFSS (High Frequency Structural Simulator). The top and back view of the prototype is shown in Figures 4 and 5. The measured and simulated reflection coefficients of the proposed 2 x 1 array are illustrated in Figure-6.

The simulated return loss of the array antenna for GPS L1 and L5 frequency band is -35 dB and -27 dB respectively having -10 dB as reference. The measured return loss appears to be -27 dB and -18 dB at L1 and L5 band respectively was obtained by using Network analyzer which can further be improved by good testing environment. There is a little variation between the simulated and measured results due to SMA connector, cable effects and fabrication imperfection.

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Figure-4. Top view of the prototype.

Figure-5. Back view of the prototype.

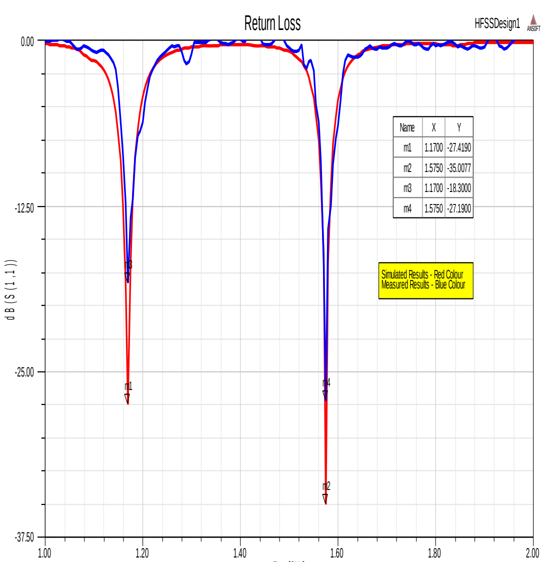

Figure-6. Simulated and measured reflection coefficients of the proposed antenna.

Figure-7 shows simulated and measured VSWR of the array antenna at GPS L1 and L5 frequency band. The simulated results of the VSWR for GPS L1 and L5 frequency band is 0.30 and 0.73, whereas measured result is of 1.09 and 1.76. The impedance matching chart given in the Figure-8 shows that L1 and L5 band has 51.79Ω and 45.92Ω impedance matching, respectively.

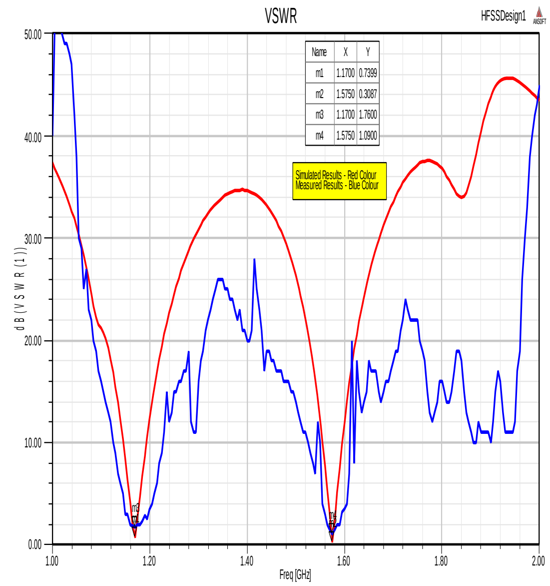

Figure-7. Simulated and measured VSWR of the proposed antenna.

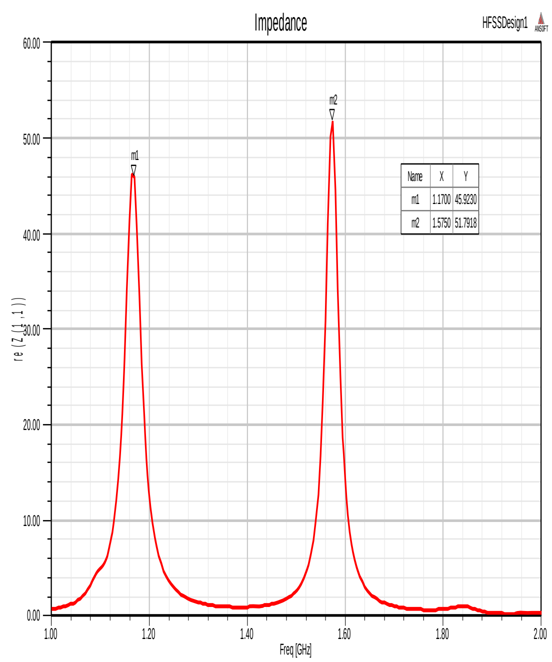

Figure-8. Simulated impedance value of the proposed antenna.

The amount of energy radiated from the antenna is graphically shown in the radiation pattern of the proposed antenna is given in the following Figure-9. For GPS L1 and L5, the amount of energy radiated is given as 2.95 dB and 15.70 dB, respectively.

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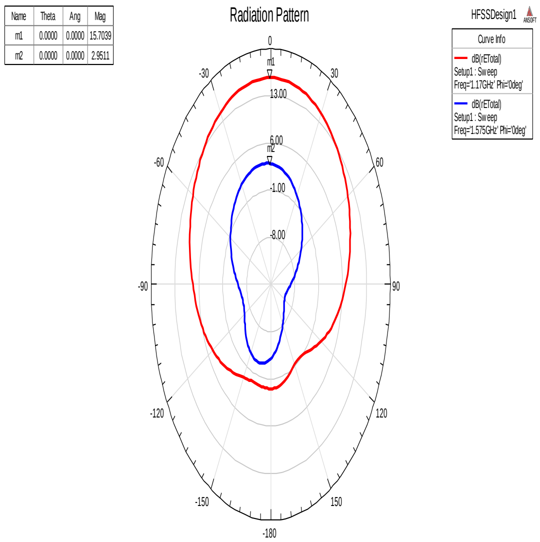

Figure-9. Radiation pattern of the proposed antenna.

The directivity of the proposed array antenna is depicted in the Figure-10. The directivity for GPS L1 and L5 is given as 2.63 dB and 4.55 dB, respectively.

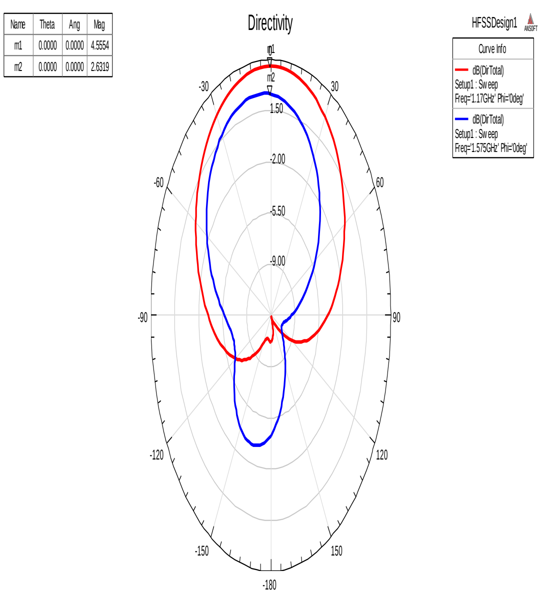

Figure-10. Directivity of the proposed antenna.

Comparative analysis of simulated and measured results

Table-1. Comparative analyses.

GPS band	Simulated results			Measured results		
	Return loss (dB)	VSWR	Impedance matching (Ω)	Return loss (dB)	VSWR	Impedance matching (Ω)
L1	-35	0.30	51.79	-27	1.09	48.10
L5	-27	0.73	45.92	-18	1.76	43.91

4. CONCLUSIONS

An 'H' shaped dual band micro-strip patch antenna array for GPS receivers has been proposed. The antenna supports a dual band operation with good performance in GPS L1 and L5 frequency bands. The dual band operation has been obtained by cutting vertical and horizontal slots in the patch antenna. The simulated and measured results yield better reflection coefficients, VSWR and impedance matching at both GPS L1 and L5 frequency bands. Further, the efficiency of the proposed antenna in all aspects can be enhanced with single feed power divider mechanism.

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